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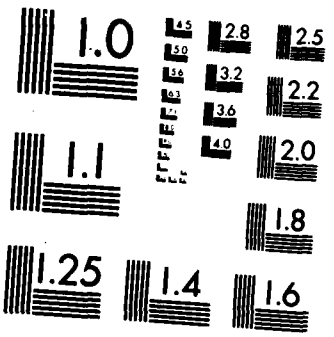

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Peter V. Hobbs

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The University of Washington's CYCLonic Extratropical Storms (CYCLES) Field Project was designed to provide measurements and observations on the mesoscale organization of precipitation, and precipitation-producing mechanisms, in extratropical cyclones. A series of field studies, employing radars, aircraft, rawinsondes and ground measurements, were carried out off the coast of Washington State during the period 1973-1982. During the period covered by this contract (1981-1985) emphasis has been on analysis and interpretation of the CYCLES field data. Precipitation was found to be organized on the mesoscale into seven different types of rainbands, located in different regions of the cyclone. The air motions, cloud structure and precipitation-producing mechanisms have been documented in each of these rainbands. Numerical models for exploring cloud and precipitation physics and chemistry have been developed for several of the rainbands. Dynamical mechanisms responsible for the formation and maintenance of the rainbands have also been explored.

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FINAL REPORT FOR CONTRACT AFOSR-ISSA 84-00046: ANALYSES OF THE CYCLES DATA SET IN EXTRATROPICAL CYCLONES AND COMPARISONS WITH NUMERICAL MODELS

1. RESEARCH OBJECTIVES

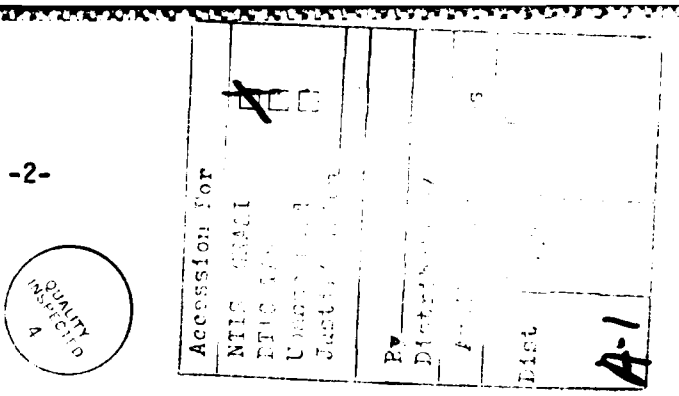
During the period 1973-1982 the University of Washington Cloud Physics Group carried out a series of field studies to explore the mesoscale and microscale structure of clouds and precipitation in winter extratropical cyclones in the Pacific Northwest (for a review see: Hobbs, P. V., 1978, Rev. Geophys. Space Phys., 16, 741-755). This project was called CYCLES (for CYCLonic Extratropical Storms).

The principal objectives of the work carried out during the period 1981-1985, under grants from the National Science Foundation and Contract AFOSR-ISSA 84-00046, were to further analyze and interpret the CYCLES data set through diagnostic and numerical modeling studies.

2. PRINCIPAL FINDINGS

The principal accomplishments during the period 1981-1985 may be summarized as follows:

- The airflow and cloud structure associated with the narrow (but intense) rainband that is often associated with a cold front have been documented in detail on both the small mesoscale and the microscale (see P. V. Hobbs and P.O.G. Persson, 1982: J. Atmos., 39, 280-295).
- Small wave-like rainbands associated with a cold-frontal zone and an occlusion have been analyzed and mechanisms for their formation have been proposed (see P.-Y. Wang, D. B. Parsons and P. V. Hobbs, 1983: J. Atmos. Sci., 40, 543-558 and P.-Y. Wang and P. V. Hobbs, 1983: J. Atmos. Sci., 40, 1950-1964).



2. PRINCIPAL FINDINGS (Continued):

- The formation, development, interaction and dissipation of rainbands have been documented and analyzed (see D. B. Parsons and P. V. Hobbs, 1983: J. Atmos. Sci., 40, 559-579).
- The effects of orography on rainbands have been investigated (see D. B. Parsons and P. V. Hobbs, 1983: J. Atmos. Sci., 40, 1930-1949).
- Various dynamical mechanisms and theories for the formation of mesoscale rainbands have been compared with CYCLES data and the most likely mechanisms identified (see D. B. Parsons and P. V. Hobbs, 1983: J. Atmos Sci., 40, 2377-2397).
- The mesoscale structure of comma clouds (or polar lows) has been documented (S. Businger and P. V. Hobbs, submitted for publication to Mon. Wea. Rev.)
- Numerical models to simulate the formation of clouds and precipitation in warm-frontal and narrow cold-frontal rainbands have been developed and tested against CYCLES data (see S. A. Rutledge and P. V. Hobbs, 1983: J. Atmos. Sci., 40, 1185-1206 and S. A. Rutledge and P. V. Hobbs, 1984: J. Atmos. Sci., 41, 2949-2972).
- A 2-dimensional, primitive equation model, with water vapor and parameterized cloud physics, is being used to see whether a cold front, with associated rainbands, can be modelled. This numerical model will also be used to diagnose the dynamical mechanisms responsible for the formation of the rainbands (This work is still in progress).

2. PRINCIPAL FINDINGS (Continued):

- Airborne data collected in CYCLES have been used to determine the size spectra of ice particles in frontal clouds and their deviations from an exponential size distribution (see P. H. Herzegh and P. V. Hobbs, 1985: Quart. J. Roy. Meteor. Soc., 111, 463-477).

3. JOURNAL PUBLICATIONS

"The Mesoscale and Microscale Structure and Organization of Clouds and Precipitation in Midlatitude Cyclones. IV: Vertical Air Motions and Microphysical Structures of Prefrontal Surge Clouds and Cold-Frontal Clouds," P. H. Herzegh and P. V. Hobbs, J. Atmos. Sci., 38, 1771 (1981)

"The Mesoscale and Microscale Structure and Organization of Clouds and Precipitation in Midlatitude Cyclones. V: The Substructure of Narrow Cold-Frontal Rainbands," P. V. Hobbs and P.O.G. Persson, J. Atmos. Sci., 39, 280 (1982)

"Mesoscale Structures of Vortices in Polar Air Streams," J. D. Locatelli, P. V. Hobbs and J. A. Werth, Mon. Wea. Rev., 110, 1417 (1982)

"The Mesoscale and Microscale Structure and Organization of Clouds and Precipitation in Midlatitude Cyclones. VI: Wavelike Rainbands Associated with a Cold-Frontal Zone," P.-Y. Wang, D. B. Parsons and P. V. Hobbs, J. Atmos. Sci., 40, 543 (1983)

"The Mesoscale and Microscale Structure and Organizationof Clouds and Precipitation in Midlatitude Cyclones. VII: Formation, Development, Interaction and Dissipation of Rainbands," D. B. Parsons and P. V. Hobbs, J. Atmos. Sci., 40, 559 (1983)

"The Mesoscale and Microscale Structure and Organization of Clouds and Precipitation in Midlatitude Cyclones. VIII: A Model for the "Seeder-Feeder" Process in Warm-Frontal Rainbands," S. A. Rutledge and P. V. Hobbs, J. Atmos. Sci., 40, 1185 (1983)

"The Mesoscale and Microscale Structure and Organization of Clouds and Precipitation in Midlatitude Cyclones. IX: Some Effects of Orography on Rainbands," D. B. Parsons and P. V. Hobbs, J. Atmos. Sci., 40, 1930 (1983)

3. JOURNAL PUBLICATIONS (Continued)

"The Mesoscale and Microscale Structure and Organization of Clouds and Precipitation in Midlatitude Cyclones. X: Wavelike Rainbands in an Occlusion," P.-Y. Wang and P. V. Hobbs, J. Atmos. Sci., 40, 1950 (1983)

"The Mesoscale and Microscale Structure and Organization of Clouds and Precipitation in Midlatitude Cyclones. XI: Comparisons Between Observational and Theoretical Aspects of Rainbands," D. B. Parsons and P. V. Hobbs, J. Atmos. Sci., 40, 2377 (1983)

"The Mesoscale and Microscale Structure and Organization of Clouds and Precipitation in Midlatitude Cyclones. XII: A Diagnostic Modeling Study of Precipitation Development in Narrow Cold-Frontal Rainbands," S. A. Rutledge and P. V. Hobbs., J. Atmos Sci., 41, 2959 (1984)

"Size Spectra of Snow Particles in Frontal Clouds: Occurrence and Origins of Deviations from the Exponential Form," P. H. Herzegh and P. V. Hobbs, Quart. J. Roy. Meteor. Soc., 111, 463 (1985)

4. INTERACTIONS

(a) Conference Presentations

	Title of Paper	Authors	Conference
(i)	"Origins, Behaviors, and Interactions of Mesoscale Rainbands in Extratropical Cyclones"	D. B. Parsons P. V. Hobbs	20th AMS Conf. on Radar Meteorology, Boston, 1981
(ii)	"The Use of a Single Doppler Radar in Short-Range Forecasting and Real-Time Analysis of Extratropical Cyclones"	T. J. Matejka P. V. Hobbs	Proceedings of the IAMAP Nowcasting Symposium, Hamburg, 1981
(iii)	"Mesoscale Structure in Midlatitude Frontal Systems"	P. V. Hobbs	Proceedings of the IAMAP Nowcasting Symposium, Hamburg 1981

(a) Conferences Presentations (Continued)

	Title of Paper	Authors	Conference
(iv)	"A Case Study of Wavelike Rainbands in a Midlatitude Cyclone"	P.-Y. Wang P. V. Hobbs D. B. Parsons	AMS Conf. on Cloud Physics, Chicago, 1982
(v)	"Banded Cloud and Precipitation Structures in Extratropical Cyclones: Observations and Theories"	P. V. Hobbs	1st Conf. on Mesoscale Meteorology, Norman, OK, 1983
(vi)	"Observational and Numerical Modeling Studies of Cloud and Precipitation Processes in Rainbands in Extratropical Cyclones"	S. A. Rutledge P. V. Hobbs	9th Int'l. Cloud Physics Conf., Tallinn, 1984
(vii)	"Modelling Cloud and Mesoscale Processes"	P. V. Hobbs	19th Annual Congress of the Canadian Meteorology and Oceanographic Society (CMOS), Montreal, 1984
(viii)	"The Synoptic Climatology of Polar Low Outbreaks"	S. Businger	5th Extratropical Cyclone Project Workshop, Port Deposit, MD, 1985
(ix)	"Mesoscale Structures of Two Comma Clouds over the Pacific Ocean"	P. V. Hobbs S. Businger	2nd Conf. on Mesoscale Processes, Pennsylvania State University, University Park, PA, 1985

(b) Seminars Related to the Contract Given by Professor Peter V. Hobbs between 1981 and September 1985

(i) "The "Seeder-Feeder" Process in Stratocumulus Clouds and Extratropical Cyclones." Geophysical Sciences Dept., Univ. of Chicago, November 19, 1982.

(b) Seminars (Continued)

(ii) "Mesoscale Studies of Midlatitude Cyclones," University of California at Los Angeles (UCLA), February 17, 1982.

(iii) "Observational and Theoretical Aspects of Rainbands in Extratropical Cyclones", University of Reading, England, December 1983.

(iv) "Observations and Modelling of the 'Seeder-Feeder' Process in Precipitation Systems, Meteorological Office of the United Kingdom, Bracknell, England, 1983.

(v) "Observational and Theoretical Studies of Mesoscale Rainbands in Extratropical Cyclones". Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt e.V. (DFVLR), Institut für Physik der Atmosphäre, Münich, FRG April 3, 1984.

(vii "Studies of Mesoscale Processes and Cloud Chemistry at the University of Washington", Fraunhofer-Institut für Atmosphärische Umweltforschung, Garmisch-Partenkirchen, FRG, May 24, 1984.

(vii) "The Mesoscale and Microscale Structure and Organization of Precipitation in Cyclonic Storms", Meteorologisches Institut Universität (TH), Karlsruhe, FRG, June 15, 1984.

(viii) "The Mesoscale Structure of Extratropical Cyclones", Meteorologisches Institut der Universität München, München, FRG, July 3, 1984.

(ix) "Observational and Theoretical Studies of the Mesoscale and Microscale Structures of Extratropical Cyclones", Meteorologisches Institut der Universitat Hamburg, Hamburg, FRG, August 14, 1984.

(b) Seminars (Continued)

(ix) "Observational and Theoretical Studies of the Mesoscale and Microscale Structures of Extratropical Cyclones", Department of Meteorology, University of Helsinki, Finland, August 29, 1984.

(c) Committees

(i) Professor Peter V. Hobbs

International Commission on Cloud Physics, IAMAP (President)

Executive Committee, International Association of Meteorology and Atmospheric Physics (IAMAP)

Mesoscale Working Group, IAMAP Commission on Dynamic Meteorology

Genesis of Atlantic Lows Experiment (GALE), Steering Committee

Experimental Design Panel (GALE) Chairman

(ii) Professor Lawrence F. Radke

Cloud Physics Committee of the American Meteorological Society

Committee on Measurements of the American Meteorological Society

GLOBE Working Group of the National Aeronautical and Space Administration

Basic Research Committee of the U.S. Army

Moving and Remote Monitoring Committee of the Air Pollution Control Association

5. PARTICIPATING PROFESSIONALS

(a) Faculty

Professor Peter V. Hobbs

Professor Lawrence F. Radke

Professor Richard R. Weiss

Research Associate John D. Locatelli

5. PARTICIPATING PROFESSIONALS (Continued)

(b) Staff

Kumud R. Biswas

(c) Students

David B. Parsons

Steven A. Rutledge

Nathan T. Funk

Paul H. Herzegh

Owen Hertzman

David Knight

Steven Businger

(d) Visiting Scientists

Peng-Yun Wang - 2 Years (People's Republic of China)

Yin-Mo Zhuang - 1 Year (People's Republic of China)

Professor J. Eggers - 2 months (Federal Republic of Germany)

Dr. Yutaka Ishizaka - 1 Year (Japan)

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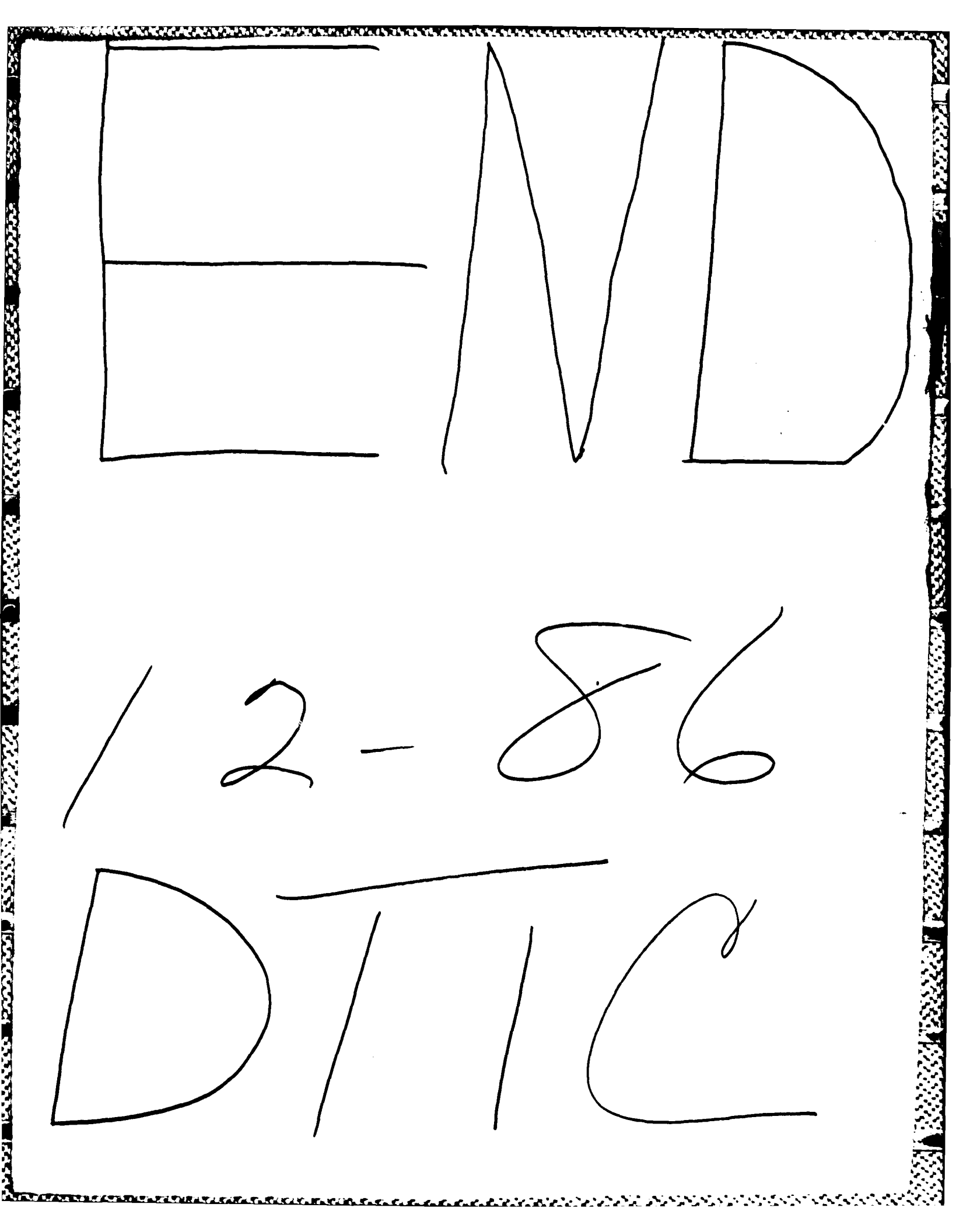
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